

Near-horizon brane-scan revived

M. J. Duff¹

Department of Physics, Imperial College London, Prince Consort Road, London SW7 2BZ

ABSTRACT

In 1987 two versions of the brane-scan of D -dimensional super p -branes were put forward. The first pinpointed those (p, D) slots consistent with kappa-symmetric Green-Schwarz type actions; the second generalized the *membrane at the end of the universe* idea to all those superconformal groups describing p -branes on the boundary of $AdS_{p+2} \times S^{D-p-2}$. Although the second version predicted $D3$ and $M5$ branes in addition to those of the first, it came unstuck because the $1/2$ BPS solitonic branes failed to exhibit the required symmetry enhancement in the near-horizon limit, except in the non-dilatonic cases $(p = 2, D = 11)$, $(p = 3, D = 10)$ and $(p = 5, D = 11)$. Just recently, however, it has been argued that the fundamental $D = 10$ heterotic string does indeed display a near-horizon enhancement to $OSp(8|2)$ as predicted by the brane-scan, provided α' corrections are taken into account. If this logic could be extended to the other strings and branes, it would resolve this 21-year-old paradox and provide a wealth of new AdS/CFT dualities, which we tabulate.

¹mduff@imperial.ac.uk

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Supergroup	AdS Dimension	p
$OSp(n_+ 2) \times OSp(n_- 2)$	3	1
$OSp(N 4)$	4	2
$SU(2, 2 N)$	5	3
$F^2(4)$	6	4
$OSp(8^* N)$	7	5

Table 2: Supergroups admitting p -branes on the boundary of $AdS_{p+2} \times S^{D-p-2}$.

formal groups in Nahm's classification [7] (listed in appendix A) with bosonic subgroups $SO(p+1, 2) \times SO(D-p-1)$ describing p -branes on the boundary of $AdS_{p+2} \times S^{D-p-2}$, as shown in Table 2. In each case the boundary CFT is described by the corresponding singleton (scalar), doubleton (scalar or vector) or triplet (scalar or tensor) supermultiplet². The supersingleton lagrangian and transformation rules were also spelled out explicitly in this paper. The resulting brane-scans are shown in Tables 4, 5 and 6, where $d = p + 1$. The number of dimensions transverse to the brane, $D - d$, equals the number of scalars in the singleton, doubleton or triplet supermultiplet, as shown in Table 3. Once again at this stage we are considering only 1/2 BPS branes in uncompactified spacetimes. The two factors appearing in the $d = 2$ case is simply a reflection of the ability of strings to have right and left movers. For brevity, we have written the Type II assignments in Table 4, but more generally we could have $OSp(n_+|2) \times OSp(n_-|2)$ where n_+ and n_- are the number of left and right supersymmetries [9].

Note that Table 4 reproduces the same twelve points as Table 1. However, Tables 5 and 6 predicted new branes including what would later be called the $D3$ and $M5$ branes, which at the time were more mysterious.

In early 1988, Nicolai, Sezgin and Tani [10] independently put forward the same generalization of the *membrane at the end of the universe* idea, spelling out the doubleton and triplet lagrangian and transformation rules, in addition to the singleton. However, by insisting on only scalar supermultiplets their list corresponded to the branes of Table 4, but not those of Tables 5 and 6. In this case, as they note, the spheres happen to be the parallelizable ones S^1 , S^3 and S^7 .

Notwithstanding the agreement between the (p, D) slots in Table 4 and Table 1 and

²Our nomenclature is based on the rank of AdS_{p+2} and differs from that of Günaydin [8].

D	Supergroup	Supermultiplet	Field content
10	$OSp(8|2)$	$((n_+, n_-) = (8, 0), d = 2)$ singleton	8 spinors, 8 scalars
6	$OSp(4|2)$	$((n_+, n_-) = (4, 0), d = 2)$ singleton	4 spinors, 4 scalars,
4	$OSp(2|2)$	$((n_+, n_-) = (2, 0), d = 2)$ singleton	2 spinors, 2 scalars
3	$OSp(1|2)$	$((n_+, n_-) = (1, 0), d = 2)$ singleton	1 spinor, 1 scalar
11	$OSp(8|4)$	$(n = 8, d = 3)$ singleton	8 spinors, 8 scalars
7	$OSp(4|4)$	$(n = 4, d = 3)$ singleton	4 spinors, 4 scalars
5	$OSp(2|4)$	$(n = 2, d = 3)$ singleton	2 spinors, 2 scalars
4	$OSp(1|4)$	$(n = 1, d = 3)$ singleton	1 spinor, 1 scalar
8	$SU(2, 2|2)$	$(n = 2, d = 4)$ doubleton	2 spinors, 4 scalars
6	$SU(2, 2|1)$	$(n = 1, d = 4)$ doubleton	1 spinor, 2 scalars
9	$F^2(4)$	$(n = 2, d = 5)$ doubleton	2 spinors, 4 scalars
10	$OSp(8^*|2)$	$((n_+, n_-) = (1, 0), d = 6)$ tripleton	2 spinors, 4 scalars
10	$SU(2, 2|4)$	$(n = 4, d = 4)$ doubleton	1 vector, 4 spinors, 6 scalars
6	$SU(2, 2|2)$	$(n = 2, d = 4)$ doubleton	1 vector, 2 spinors, 2 scalars
4	$SU(2, 2|1)$	$(n = 1, d = 4)$ doubleton	1 vector, 1 spinor
11	$OSp(8^*|4)$	$((n_+, n_-) = ((2, 0), d = 6)$ tripleton	1 chiral 2-form, 4 spinors, 5 scalars
7	$OSp(8^*|2)$	$((n_+, n_-) = ((1, 0), d = 6)$ tripleton	1 chiral 2-form, 2 spinors, 1 scalar

Table 3: Superconformal groups and their singleton, doubleton and tripleton representations. $D = d + \text{number of scalars}$.

D↑								
11	.		OSp(8|4)					
10	.		$[OSp(8|2)]^2$			$OSp(8^*|2)$		
9	.				$F^2(4)$			
8	.				$SU(2, 2|2)$			
7	.		$OSp(4|4)$					
6	.		$[OSp(4|2)]^2$		$SU(2, 2|1)$			
5	.		$OSp(2|4)$					
4	.		$[OSp(2|2)]^2$	$OSp(1|4)$				
3	.		$[OSp(1|2)]^2$					
2	.							
1	.							
0	.	.	.	.	.	.	.
	0	1	2	3	4	5	6	d→

Table 4: The brane-scan of superconformal groups admitting scalar supermultiplets: singletons ($p = 1, 2$), doubletons ($p = 3, 4$) and tripletons ($p = 5$).

D↑								
11	.							
10	.				SU(2, 2|4)			
9	.							
8	.							
7	.							
6	.				<i>SU(2, 2|2)</i>			
5	.							
4	.				<i>SU(2, 2|1)</i>			
3	.							
2	.							
1	.							
0	.	.	.	.	.	.	.
	0	1	2	3	4	5	6	d→

Table 5: The brane-scan of superconformal groups admitting vector supermultiplets: doubletons ($p = 3$).

$D\uparrow$								
11	.						$\mathbf{OSp}(8^*|4)$	
10	.							
9	.							
8	.							
7	.						$OSp(8^*|2)$	
6	.							
5	.							
4	.							
3	.							
2	.							
1	.							
0	.	.	.	.	.	.	.
	0	1	2	3	4	5	6	$d\rightarrow$

Table 6: The brane-scan of superconformal groups admitting tensor supermultiplets: tripletons ($p = 5$).

notwithstanding the prediction of new branes in Tables 5 and 6, including $D3$ and $M5$, the *end of the universe* brane-scans suffered from the following problem: Although the corresponding D -dimensional supergravity theories all admit compactifications to $AdS_{p+2} \times S^{D-p-2}$, the resulting bosonic symmetry is not in general $SO(p+1, 2) \times SO(D-p-1)$ and hence the resulting supergroups are not those of Table 2. For example, Type I supergravity in $D = 10$ admits solutions of the form $AdS_7 \times S^3$ and $AdS_3 \times S^7$ but there is a non-constant dilaton whose gradient acts as a conformal AdS Killing vector [11]. So the symmetries are not $OSp(8|2)$ or $OSp(8^*|2)$ as required by the brane-scan. Exceptions to this rule are provided by the non-dilatonic solutions $(p = 2, D = 11)$, $(p = 3, D = 10)$ and $(p = 5, D = 11)$ denoted in boldface in Tables 4, 5 and 6.

This problem raised its head once more with the arrival of 1/2 BPS solitonic p -branes [19] which, with the above exceptions [12], failed to exhibit the required symmetry enhancement in the near-horizon limit [13], as described in Section 2.

Just recently, however, it has been argued by Dabholkar and Murthy [14] and by Lapan, Simons and Strominger [15], that the fundamental $D = 10$ heterotic string [16, 35] does indeed display a near-horizon enhancement to $OSp(8|2)$ as predicted by the brane-scan, provided α' corrections are taken into account. See also Johnson [17] and Kraus, Larsen and Shah [18]. This is taken up in Section 4.

2 The near-horizon geometry problem

AdS emerges in the near-horizon geometry of black p -brane solutions [12, 13, 19] in D dimensions. The dual brane, with worldvolume dimension $\tilde{d} = D - d - 2$, interpolates between D -dimensional Minkowski space M_D and $AdS_{\tilde{d}+1} \times S^{d+1}$ (or $M_{\tilde{d}+1} \times S^3$ if $d = 2$). To see this, we recall that such branes arise generically as solitons of the following action [21]:

$$I = \frac{1}{2\kappa_D^2} \int d^D x \sqrt{-g} \left[R - \frac{1}{2}(\partial\phi)^2 - \frac{1}{2(d+1)!} e^{-\alpha\phi} F_{d+1}^2 \right] \quad (2.1)$$

where F_{d+1} is the field strength of a d -form potential A_d and α is the constant

$$\alpha^2 = 4 - \frac{2d\tilde{d}}{d+\tilde{d}} \quad (2.2)$$

Written in terms of the $(d-1)$ -brane sigma-model metric $e^{-\alpha/d\phi} g_{MN}$, the solutions are [21, 19]

$$ds^2 = H^{\frac{2-d}{d}} dx^\mu dx_\mu + H^{2/d} (dy^2 + y^2 d\Omega_{d+1}^2)$$

$$e^{2\phi} = H^\alpha$$

$$F_{d+1} = dL^d \epsilon_{d+1} \quad (2.3)$$

where

$$H = 1 + \frac{L^d}{y^d} \quad (2.4)$$

For a stack of N singly charged branes $L^d = Nb^d$ and the near horizon, or large N , geometry corresponds to

$$ds^2 \sim \left(\frac{y}{L}\right)^{2-d} dx^\mu dx_\mu + \frac{L^2}{y^2} dy^2 + L^2 d\Omega_{d+1}^2 \quad (2.5)$$

Or, defining the new coordinate

$$y = Le^{\zeta/L} \quad (2.6)$$

we get

$$\begin{aligned} ds^2 &\sim e^{\frac{2-d}{L}\zeta} dx^\mu dx_\mu + d\zeta^2 + L^2 d\Omega_{d+1}^2 \\ \phi &\sim \frac{d\alpha}{2L} \zeta \\ F_{d+1} &\sim dL^d \epsilon_{d+1} \end{aligned} \quad (2.7)$$

Thus for $d \neq 2$ the near-horizon geometry is $AdS_{\tilde{d}+1} \times S^{d+1}$. Note, however, that the gradient of the dilaton is generically non-zero and plays the role of a conformal Killing vector on $AdS_{\tilde{d}+1}$. Consequently, there is no enhancement of symmetry in the near-horizon limit. The unbroken supersymmetry remains one-half and the bosonic symmetry remains $P_{\tilde{d}} \times SO(d+2)$. (If $d = 2$, then (2.7) reduces to

$$\begin{aligned} ds^2 &\sim dx^\mu dx_\mu + d\zeta^2 + L^2 d\Omega_3^2 \\ \phi &\sim \frac{\alpha}{L} \zeta \\ F_3 &\sim 2L^2 \epsilon_3 \end{aligned} \quad (2.8)$$

which is $M_{\tilde{d}+1} \times S^3$, with a linear dilaton vacuum. The bosonic symmetry remains $P_{\tilde{d}} \times SO(4)$.)

Of particular interest are the ($\alpha = 0$) subset of solitons for which the dilaton is zero or constant: the *non-dilatonic p-branes*. From (2.2) we see that for branes with one kind of charge there are only 3 cases:

$$D = 11 : d = 6, \tilde{d} = 3$$

$$D = 10 : d = 4, \tilde{d} = 4$$

$$D = 11 : d = 3, \tilde{d} = 6$$

which are precisely the three cases of M2 [20], D3 [33, 30] and M5 [37] that occupied privileged positions in Tables 4, 5 and 6. Then the near-horizon geometry coincides with the

$AdS_{\tilde{d}+1} \times S^{d+1}$ non-dilatonic maximally symmetric compactifications of the corresponding supergravities. The supersymmetry doubles and the bosonic symmetry is also enhanced to $SO(\tilde{d}, 2) \times SO(d+2)$. Thus the total symmetry is given by the conformal supergroups $OSp(8|4)$, $SU(2, 2|4)$ and $OSp(8^*|4)$, respectively.

Thus we see that not all branes are created equal. A *p-brane aristocracy* obtains whose members are those branes whose near-horizon geometries have as their symmetry the conformal supergroups. As an example of a plebeian brane we can consider the ten-dimensional superstring:

$$D = 10 : d = 6, \tilde{d} = 2$$

whose near-horizon geometry is $AdS_3 \times S^7$ but with a non-trivial dilaton which does not have the conformal group $OSp(8|2)$ as its symmetry, even though this group appears in the $(D = 10, \tilde{d} = 2)$ slot on the scalar brane-scan of Table 4. Such mismatches were the primary reason that the near-horizon brane-scan slipped into oblivion, but we shall consider its revival in Section 4.

3 Generalizations

3.1 New kappa-symmetric brane-scan

An equivalent way to arrive at the Green-Schwarz brane-scan of Table 1 is to list all scalar supermultiplets in $d \geq 2$ dimensions and to interpret the dimension of the target space, D , by

$$D - d = \text{number of scalars.} \quad (3.1)$$

In particular, we can understand $d_{\text{max}} = 6$ from this point of view since this is the upper limit for scalar supermultiplets. However, with the discovery in 1990 of Type II *p*-brane solitons [31, 32, 33, 30, 34], and with the discovery in 1992 of the *M*-theory 5-brane [37], vector and tensor multiplets were also seen to play a role. These developments gave rise to the new kappa-symmetric brane-scan [34, 19] of Table 7.

In particular, the worldvolume fields of the self-dual Type IIB super 3-brane were shown to be described by an $(n = 4, d = 4)$ gauge theory [30], which on the boundary of AdS_5 is just the doubleton supermultiplet of the superconformal group $SU(2, 2|4)$! Similarly, the worldvolume fields of the *M*-theory 5-brane were shown to be described by an $((n_+, n_-) = (2, 0), d = 6)$ multiplet with a chiral 2-form, 8 spinors and 5 scalars [12], which on the boundary of AdS_7 is just the tripleton supermultiplet of the superconformal

$D \uparrow$														
11	.			S			T							
10	.	V	S/V	V	V	V	S/V	V	V	V	V			
9	.	S				S								
8	.				S									
7	.			S			T							
6	.	V	S/V	V	S/V	V	V							
5	.	S		S										
4	.	V	S/V	S/V	V									
3	.	S/V	S/V	V										
2	.	S												
1	.													
0	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	0	1	2	3	4	5	6	7	8	9	10	11	$d \rightarrow$	

Table 7: The new kappa-symmetric brane-scan, where S , V and T denote scalar, vector and antisymmetric tensor multiplets.

group $OSp(8^*|4)!$ (These zero modes are the same as those of the Type IIA 5-brane, found previously in [31, 32]).

So although the confirmation of the Type II 3-brane and M-theory 5-brane should have provided a feather in the cap of the near-horizon brane-scan, the failure of all the other branes, except the M-theory 2-brane, to exhibit a near-horizon symmetry enhancement still blighted its success.

With the inclusion of branes with vector and tensor supermultiplets on their worldvolume, another curiosity arises. Whereas the near-horizon brane-scan of Table 4 exhausts all the scalar branes and the near-horizon brane-scan of Table 6 exhausts all the tensor branes, the near-horizon brane scan of Table 5 is only a subset of all the vector branes [36]. The Type IIB 3-brane is special because gauge theories are conformal only in $d = 4$. Branes with vectors on their worldvolume in $d \neq 4$ are doomed to remain forever plebeian³.

³Not counting $d = 3$ Chern-Simons models.

3.2 Intersecting branes

So far we have considered only single 1/2 BPS branes but intersecting branes with less supersymmetry can also exhibit AdS near-horizon geometry. For bound states of branes with M kinds of charge, the constant α of Section 2 gets replaced by [22, 23, 24]

$$\alpha^2 = \frac{4}{M} - \frac{2d\tilde{d}}{d + \tilde{d}} \quad (3.2)$$

A non-dilatonic solution ($\alpha=0$) occurs for $M = 2$:

$$D = 6 : d = 2, \tilde{d} = 2$$

which is just the dyonic string [25], of which the self-dual string [21] is a special case, whose near-horizon geometry is $AdS_3 \times S^3$. For $M = 3$ we have

$$D = 5 : d = 2, \tilde{d} = 1$$

which is the 3-charge black hole [26], whose near-horizon geometry is $AdS_2 \times S^3$, and

$$D = 5 : d = 1, \tilde{d} = 2$$

which is the 3-charge string [26] whose near-horizon geometry is $AdS_3 \times S^2$. For $M = 4$ we have

$$D = 4 : d = 1, \tilde{d} = 1$$

which is the 4-charge black hole [27, 28], of which the Reissner-Nordström solution is a special case [22], and whose near-horizon geometry is $AdS_2 \times S^2$ [29].

3.3 Other signatures

The *p-brane at the end of the universe* idea may also be applied in different spacetime signatures. See [40, 41, 45] for a discussion of the corresponding superconformal groups.

3.4 Compactifications

So far we have considered only uncompactified branes with near horizon geometry $AdS_{p+2} \times S^{D-p-2}$. One might also consider critical (or non-critical) strings and branes compactified on T^k , for example. Then the brane-scan would suggest near-horizon geometries of the form $AdS_{p+2} \times S^{D-k-p-2} \times T^k$. This enlarges the class of supergroups as candidate near-horizon symmetries to others listed in Table 14 of Appendix A that we have until now ignored. These are treated in Section 4.

3.5 0-branes

Similarly, the brane-scans of Section 1 focussed on $p \geq 1$ branes, but as discussed above 0-branes, i.e. black holes, also have interesting AdS_2 near-horizon geometries also treated in Section 4.

3.6 D-branes and AdS/CFT

Maldacena's conjectured duality between physics in the bulk of AdS and a conformal field theory on the boundary [46] naturally prompts comparisons with the *membrane at the end of universe* [5, 6, 4, 42, 43, 38, 39, 44, 45], whereby the p -brane occupies the boundary of AdS_{p+2} and is described by a superconformal theory and to the *membrane/supergravity bootstrap* [5, 6, 4] which conjectured that the dynamics of the supergravity in the bulk of AdS was dictated by the membrane on its boundary and vice-versa. For example, one immediately recognizes that the dimensions and supersymmetries of the three conformal theories in Maldacena's duality are exactly the same as the boldface singleton, doubleton and tripleton supermultiplets of Tables 4, 5 and 6.

The main difference is that in the older work attention was focussed on *free* superconformal theories on the boundary as opposed to the *interacting* theories considered by Maldacena. For example, although the worldvolume fields of the Type IIB 3-brane were known to be described by an $(n = 4, d = 4)$ gauge theory [30], we now know that this brane admits the interpretation of a Dirichlet brane [47] and that the superposition of N such branes yields a *non-abelian* $SU(N)$ gauge theory [48]. So the whole large N connection was missing. Important though this omission was, it does not impair the usefulness of the near-horizon brane-scan, were it proved to be correct. The assumption that it works for all the superconformal groups in Appendix A (and those of other signatures too), predicts a wealth of yet more holographic duals to which we now turn.

4 New developments

4.1 α' corrections

The new developments we have in mind begin with observation that higher order corrections can stretch the horizon of extremal small black holes leading to the non-singular $AdS_2 \times S^{D-2}$ near-horizon geometry [49].

In particular for $D = 5$ supergravity, coming from strings on T^5 or M on Calabi-Yau,

the exact supersymmetric completion of the R^2 terms has been worked out [50] and the non-singular $AdS^2 \times S^3 \times T^5$ near-horizon geometry has been established [51, 52, 53, 54, 55, 17, 56]. Sure enough, the supergroups $OSp(4^*|4) \times SU(2)$ for $N = 4$ and $OSp(4^*|2) \times SU(2)$ for $N = 2$ make their appearance, to be compared with $SU(2|1,1) \times SU(2)$ for the large black hole [57].

Similarly for black strings compactified to five dimensions, one finds that higher-order corrections lead to a near-horizon geometry $OSp(4^*|4)$ and it is conjectured that similar symmetry enhancement occurs for other compactifications [14, 15, 17, 18, 58]. In particular, the uncompactified $D = 10$ heterotic string [16] is expected to display a near-horizon $OSp(8|2)$ symmetry, as predicted in 1987 by the near-horizon brane-scan Table 4. Candidates for near-horizon supergroups of Type II strings can also be obtained by taking left and right copies of the above, again as predicted.

4.2 The heterotic near-horizon brane-scan

We now explore which near-horizon geometries are in principle allowed by the superconformal groups admitting 16 supercharges listed in Appendix A.2, where we have focussed on those admitting bosonic symmetries $SO(p+2,2) \times SO(9-k-p) \times SO(k)$ listed in Table 9 corresponding to the $AdS_{p+2} \times S^{8-k-p} \times T^k$ compactifications of Table 8. Following [14, 15], there is a geometrical $SO(p+2,2) \times SO(9-k-p)$ coming from the $AdS_{p+2} \times S^{8-k-p}$ factor and an $SO(k)$ R-symmetry coming from the T^k factor.

The resulting superconformal groups are listed in the heterotic near-horizon brane -scan of Table 10. Some caveats are in order:

1) This scan is for single fundamental branes compactified on a torus. Stacked, intersecting and/or dyonic branes with different compactifications might lead to more possibilities from Table 14.

2) This is just a list of *possibilities*; we have no idea whether they correspond to actual solutions to the α' -corrected field equations.

3) In particular, we are not sure that one should include $AdS \times$ (flat space) cases since these may not be good solutions even with higher derivatives. These can easily be removed, if necessary.

4) Since we are interested here in heterotic compactifications, we have omitted those superconformal groups in A.2 with right-moving supersymmetries. In particular we have no entry for strings on $AdS_3 \times S^3 \times T^4$ where one finds $D(2,1:\alpha) \times D(2,1:\alpha)$ in [15]. The other string entries coincide with those in [15].

5) Note that in Table 9 there is a nice match with the extra $SU(2)$ for $(N = 2; p = 3, 4, 5)$ singletons discussed in [10] but $p = 2$ is strange from this perspective.

6) The question marks in Table 10 indicate more bosonic symmetry than expected from Table 9. The meaning of this is unclear.

As a consistency check, we reproduce the $D = 5$ results for both strings and black holes discussed in the previous subsection.

As another consistency check, the heterotic superstrings at the end of $AdS_3 \times S^7$ would have to be given by the $(8_c, 0)$ superconformally invariant two-dimensional singleton field theories of the three-dimensional AdS supergroups $OSp(8|2)_c \otimes SO(2, 1)$. Fortunately, this is indeed the case, as was shown by Gunaydin, Nilsson, Sierra and Townsend [9] in 1986.

4.3 The M/Type II near-horizon brane-scan

We now explore which near-horizon geometries are in principle allowed by the superconformal groups admitting 32 supercharges listed in Appendix A.1, where we have again focussed on those admitting bosonic symmetries $SO(p + 2, 2) \times SO(D - 1 - k - p) \times SO(k)$ listed in Table 9 corresponding to the $AdS_{p+2} \times S^{D-2-k-p} \times T^k$ compactifications of Table 11.

The resulting superconformal groups are listed in the M/Type II near-horizon brane-scan of Table 13. Similar caveats apply.

Table 13 has some interesting gaps, but maybe that is just the way it is.

As a consistency check, the Type IIA and Type IIB superstrings at the end of $AdS_3 \times S^7$ would have to be given by the $(8_c, 8_s)$, $(8_c, 8_s)$ superconformally invariant two-dimensional singleton field theories of the three-dimensional AdS supergroups $OSp(8|2)_c \otimes OSp(8|2)_s$ and $OSp(8|2)_c \otimes OSp(8|2)_c$, respectively. Once again, this is indeed the case [9].

5 Conclusions

Dilatonic black holes and strings in $D = 5$ display a near-horizon symmetry enhancement when α' corrections are taken into account. If this logic could be extended to other branes in other dimensions, it would revive the near horizon brane-scan, resolve a 21-year-old paradox and provide a wealth of new AdS/CFT dualities listed in Tables 8 to 13.

6 Acknowledgements

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D↑		$AdS_4 \times S^7$	$AdS_5 \times S^5$	$AdS_7 \times S^4$
11	.			
10	.	$AdS_3 \times S^7$		
9	.	$AdS_3 \times S^6 \times T^1$		
8	.	$AdS_3 \times S^5 \times T^2$		
7	.	$AdS_3 \times S^4 \times T^3$		
6	.			
5	.	$AdS_3 \times S^2 \times T^5$		
4	.	$AdS_3 \times S^1 \times T^6$		
3	.	$AdS_3 \times T^7$		
2	.			
1	.			
0	.	.	.	.
	0	1	2	3
			4	5
			6	d→

Table 11: The $AdS_{p+2} \times S^{8-k-p} \times T^k$ geometries for 32 supercharges

D^\uparrow		$SO(3, 2) \times SO(8)$	$SO(4, 2) \times SO(6)$	$SO(6, 2) \times SO(5)$
11	.			
10	.	$SO(2, 2) \times SO(8)^2$		
9	.	$SO(2, 2) \times SO(7)^2$		
8	.	$SO(2, 2) \times SO(6)^2 \times SO(2)^2$		
7	.	$SO(2, 2) \times SO(5)^2 \times SO(3)^2$		
6	.			
5	.	$SO(2, 2) \times SO(3)^2 \times SO(5)^2$		
4	.	$SO(2, 2) \times SO(2)^2 \times SO(6)^2$		
3	.	$SO(2, 2) \times SO(7)^2$		
2	.			
1	.			
0	.	.	.	.
0	1	2	3	4
				5
				6
				$d \rightarrow$

Table 12: The bosonic subgroups for 32 supercharges

D^\uparrow		$OSp(8|4)$	$SU(2, 2|4)$	$OSp(8^*|4)$
11	.			
10	.	$OSp(8|2) \times OSp(8|2)$		
9	.	$F^0(4) \times F^0(4)$		
8	.	$SU(4|1, 1) \times SU(4|1, 1)$		
7	.	$OSp(4^*|4) \times OSp(4^*|4)$		
6	.			
5	.	$OSp(4^*|4) \times OSp(4^*|4)$		
4	.	$SU(4|1, 1) \times SU(4|1, 1)$		
3	.	$F^0(4) \times F^0(4)$		
2	.			
1	.			
0	.	.	.	.
0	1	2	3	4
				5
				6
				$d \rightarrow$

Table 13: 32 supercharges: The M/Type II near-horizon brane-scan

d	Supergroup	Bosonic subgroup	Susy
6	$OSp(8^*|N)$	$SO^*(8) \times USp(N), N \text{ even}$	$8N$
5	$F^2(4)$	$SO(5, 2) \times SU(2)$	16
4	$SU(2, 2|N)$	$SU(2, 2) \times U(N), N \neq 4$	$8N$
	$SU(2, 2|4)$	$SU(2, 2) \times SU(4)$	32
3	$OSp(N|4)$	$SO(N) \times Sp(4, R)$	$4N$
2 or 1	$OSp(N|2)$	$O(N) \times Sp(2, R)$	$2N$
	$SU(N|1, 1)$	$U(N) \times SU(1, 1), N \neq 2$	$4N$
	$SU(2|1, 1)$	$SU(2) \times SU(1, 1)$	8
	$OSp(4^*|2N)$	$SU(2) \times USp(2N) \times SU(1, 1)$	$8N$
	$G(3)$	$G_2 \times SU(1, 1)$	14
	$F^0(4)$	$Spin(7) \times SU(1, 1)$	16
	$D(2, 1; \alpha)$	$SU(2) \times SU(2) \times SU(1, 1)$	8

Table 14: Superconformal groups

A Superconformal groups

Following [7, 59, 60] we list the conformal supergroups and their bosonic subgroups in Table 14. Making use of the following isomorphisms,

$$SU(2) \sim SO(3) \sim USp(2)$$

$$SU(1, 1) \sim SO(1, 2) \sim Sp(2)$$

$$SO(4) \sim SO(3) \times SO(3)$$

$$SO(2, 2) \sim SO(1, 2) \times SO(2, 1)$$

$$SO^*(4) \sim SO(3) \times SO(1, 2)$$

$$USp(4) \sim SO(5)$$

$$Sp(4) \sim SO(3, 2)$$

$$SU(2, 2) \sim SO(4, 2)$$

we focus on those compatible with an $AdS_{p+2} \times S^{D-k-p-2} \times T^k$ geometry with either 32 or 16 supercharges. Note that the $d = 2$ cases then require either a doubling or a product with a bosonic $SO(2, 1)$ in order to contain the $SO(2, 2)$ of AdS_3 .

A.1 32 supercharges

$$d = 6 \quad OSp(8^*|4) \supset SO(6, 2) \times SO(5)$$

$$d = 4 \quad SU(2, 2|4) \supset SO(4, 2) \times SO(6)$$

$$d = 3 \quad OSp(8|4) \supset SO(3, 2) \times SO(8)$$

$$d = 2 \quad OSp(8|2) \times OSp(8|2) \supset SO(2, 2) \times SO(8) \times SO(8)$$

A.2 16 supercharges

$$d = 6 \quad OSp(8^*|2) \supset SO(6, 2) \times SO(3)$$

$$d = 5 \quad F^2(4) \supset SO(5, 2) \times SO(3)$$

$$d = 4 \quad SU(2, 2|2) \supset SO(4, 2) \times SO(3) \times U(1)$$

$$d = 3 \quad OSp(4|4) \supset SO(3, 2) \times SO(3) \times SO(3)$$

$$d = 2 \quad OSp(8|2) \times SO(1, 2) \supset SO(2, 2) \times SO(8)$$

$$d = 2 \quad F^0(4) \times SO(1, 2) \supset SO(2, 2) \times SO(7)$$

$$d = 2 \quad SU(4|1, 1) \times SO(1, 2) \supset SO(2, 2) \times SO(6) \times U(1)$$

$$d = 2 \quad OSp(4^*|4) \times SO(1, 2) \supset SO(2, 2) \times SO(5) \times SO(3)$$

$$d = 2 \quad OSp(4|2) \times OSp(4|2) \supset SO(2, 2) \times SO(3) \times SO(3) \times SO(3) \times SO(3)$$

$$d = 2 \quad OSp(5|2) \times OSp(3|2) \supset SO(2, 2) \times SO(5) \times SO(3)$$

$$d = 2 \quad OSp(6|2) \times OSp(2|2) \supset SO(2, 2) \times SO(6) \times U(1)$$

$$d = 2 \quad OSp(7|2) \times OSp(1|2) \supset SO(2, 2) \times SO(7)$$

$$d = 2 \quad D(2, 1 : \alpha) \times D(2, 1 : \alpha) \supset SO(2, 2) \times SO(3) \times SO(3) \times SO(3) \times SO(3)$$

$$d = 2 \quad SU(2|1, 1) \times SU(2|1, 1) \supset SO(2, 2) \times SO(3) \times SO(3)$$

$$d = 2 \quad OSp(4^*|2) \times OSp(4^*|2) \supset SO(2, 2) \times SO(3) \times SO(3) \times SO(3) \times SO(3)$$

$$d = 1 \quad OSp(8|2) \supset SO(1, 2) \times SO(8)$$

$$d = 1 \quad F^0(4) \supset SO(1, 2) \times SO(7)$$

$$d = 1 \quad SU(4|1, 1) \supset SO(1, 2) \times SO(6) \times U(1)$$

$$d = 1 \quad OSp(4^*|4) \supset SO(1, 2) \times SO(5) \times SO(3)$$

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